Experimental and LSP modeling study of pre-pulse effects on the laser-plasma interaction by using a 527 nm laser pulse

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Motivation

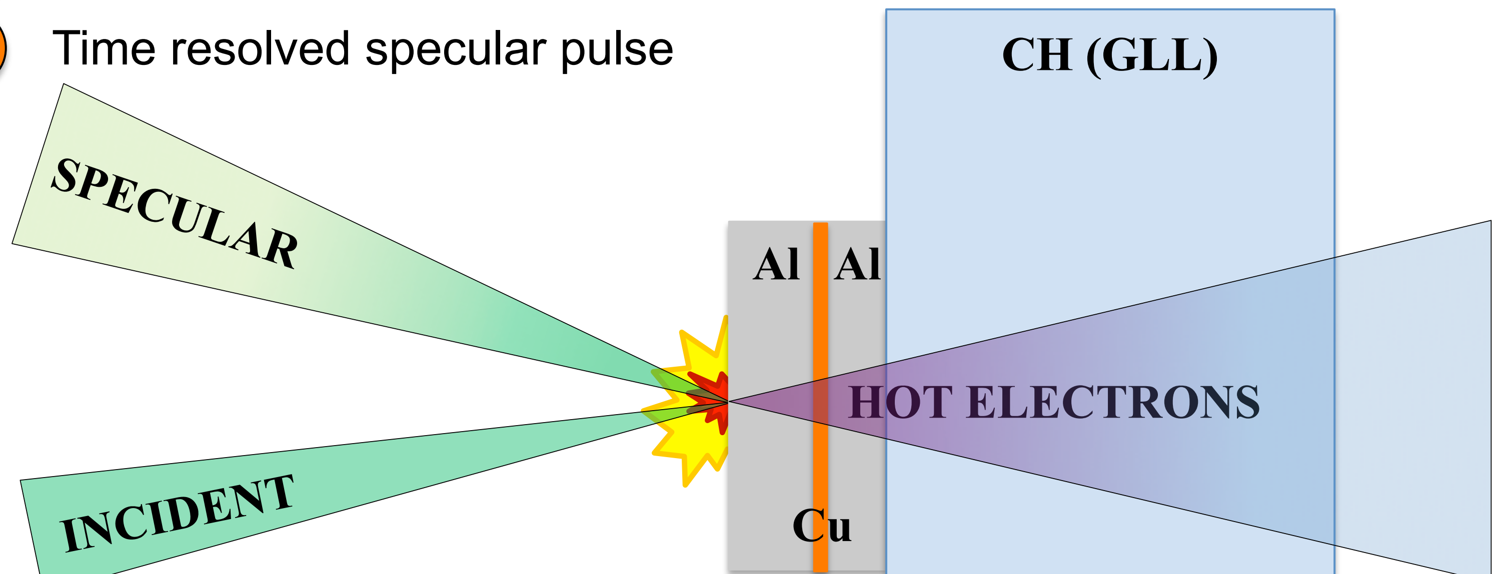
- Is a high contrast, 2ω (527 *nm*) pulse better for fast-ignition?
- High contrast pulse vs. one with pre-pulse
- Not possible to directly measure what happens in the LPI
- Fielded wide array of diagnostics for indirect measurements
- Can we simultaneously reproduce ALL these results within a single simulation to better constrain the pre-pulse effects?
- If so, then more confidently read out quantities of interest using well benchmarked simulations

We create a high contrast pulse with optional pre-pulse to study relationships between LPI and hot-electron source and transport

LLNL's Jupiter Laser Facility
2ω Titan Short Pulse

1 Specular reflectivity/absorption

2 Time resolved specular pulse

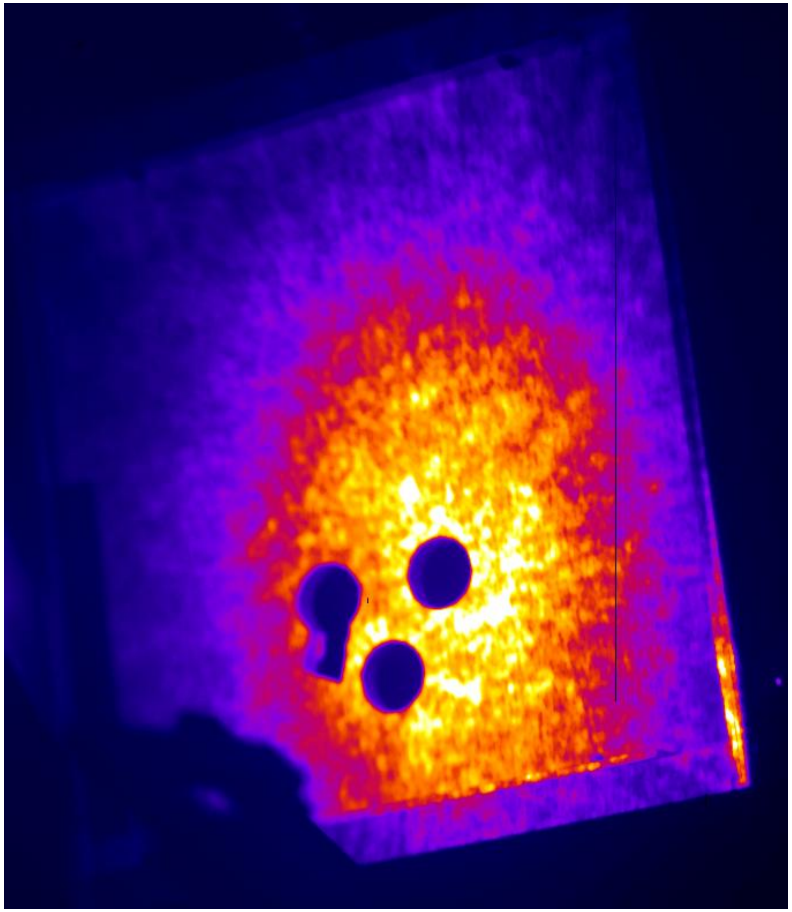


3 Electron transport

λ_o = 527 *nm* (2ω)
τ_{FWHM} = 600 *fs*
E_{total} = 50 *J*
x_{FWHM} = 8 *μm* focal spot
I_{peak} = 5 x 10^{19} *W/cm²* (a_o=3.2, E_p=1.2 *MeV*)
(Optional 3 *mJ* / 3 *ns* pre-pulse)

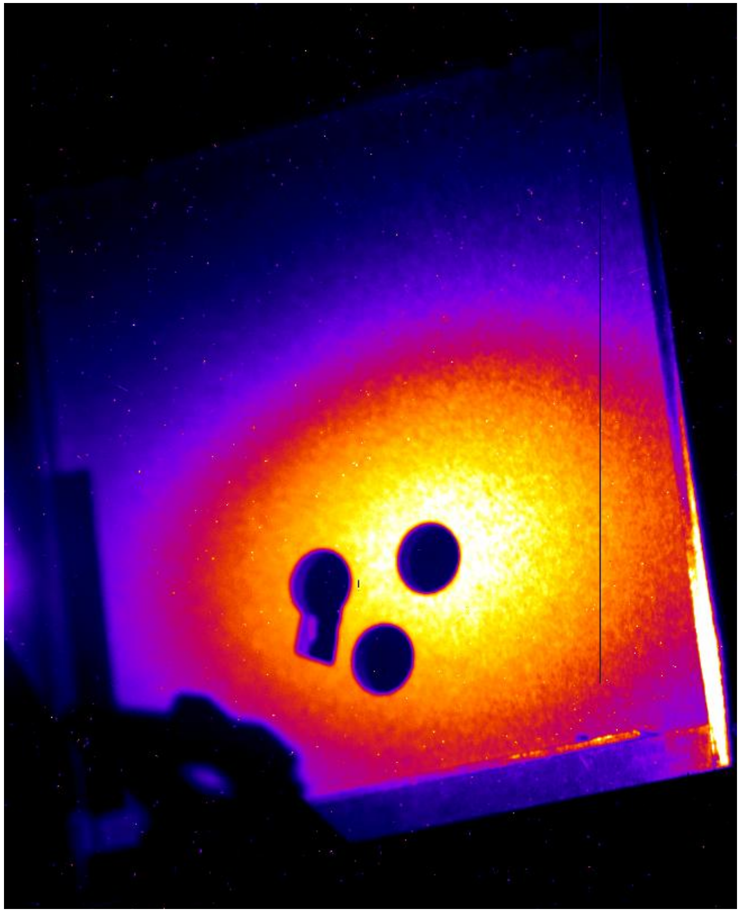
Specular reflectivity ~2x higher for no pre-pulse

No Pre-pulse



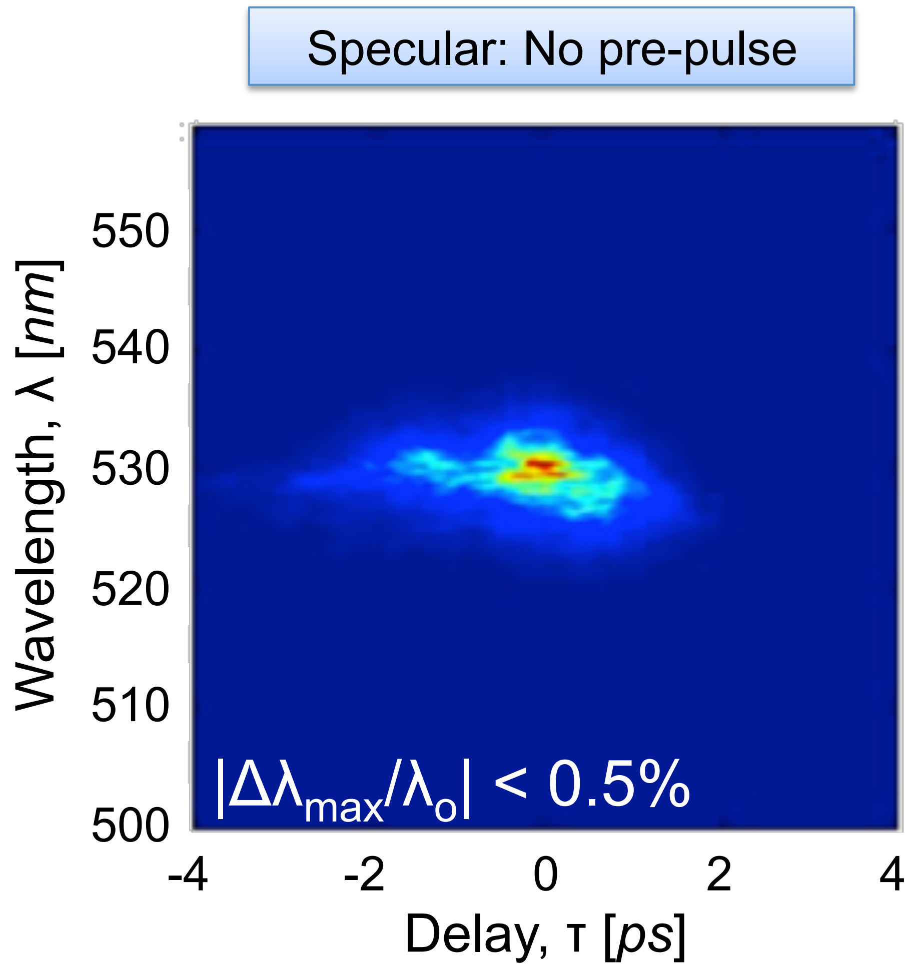
Speckled Features
25-40% Reflectivity

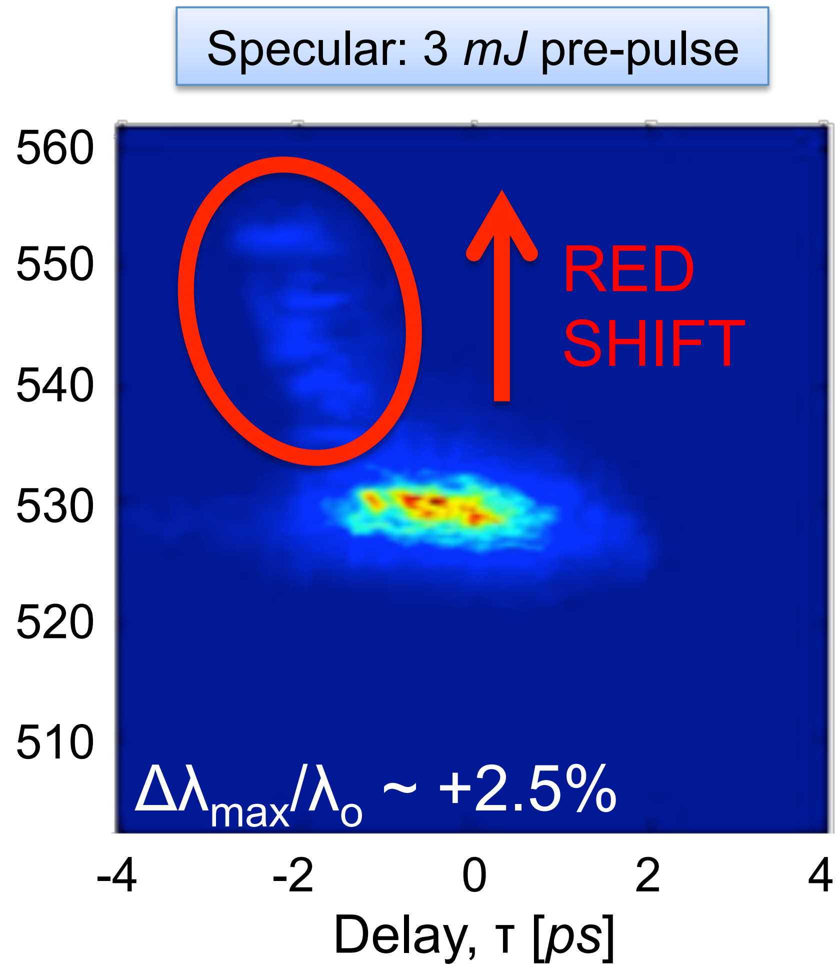
3 *mJ* Pre-pulse



Smoother beam profile
10-15% Reflectivity

Large red-shift (~2.5%) on the rising edge of specular beam with injected pre-pulse

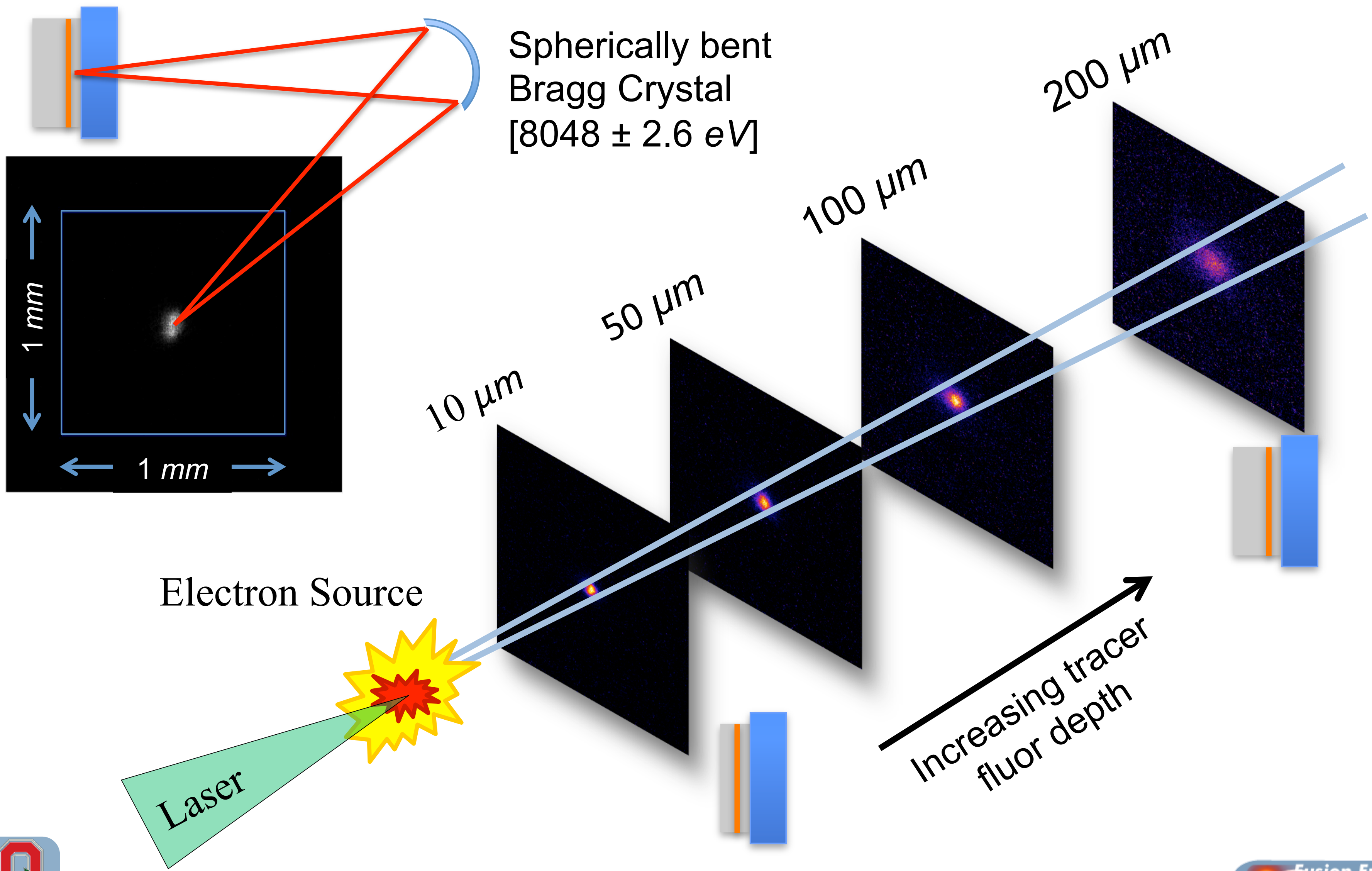




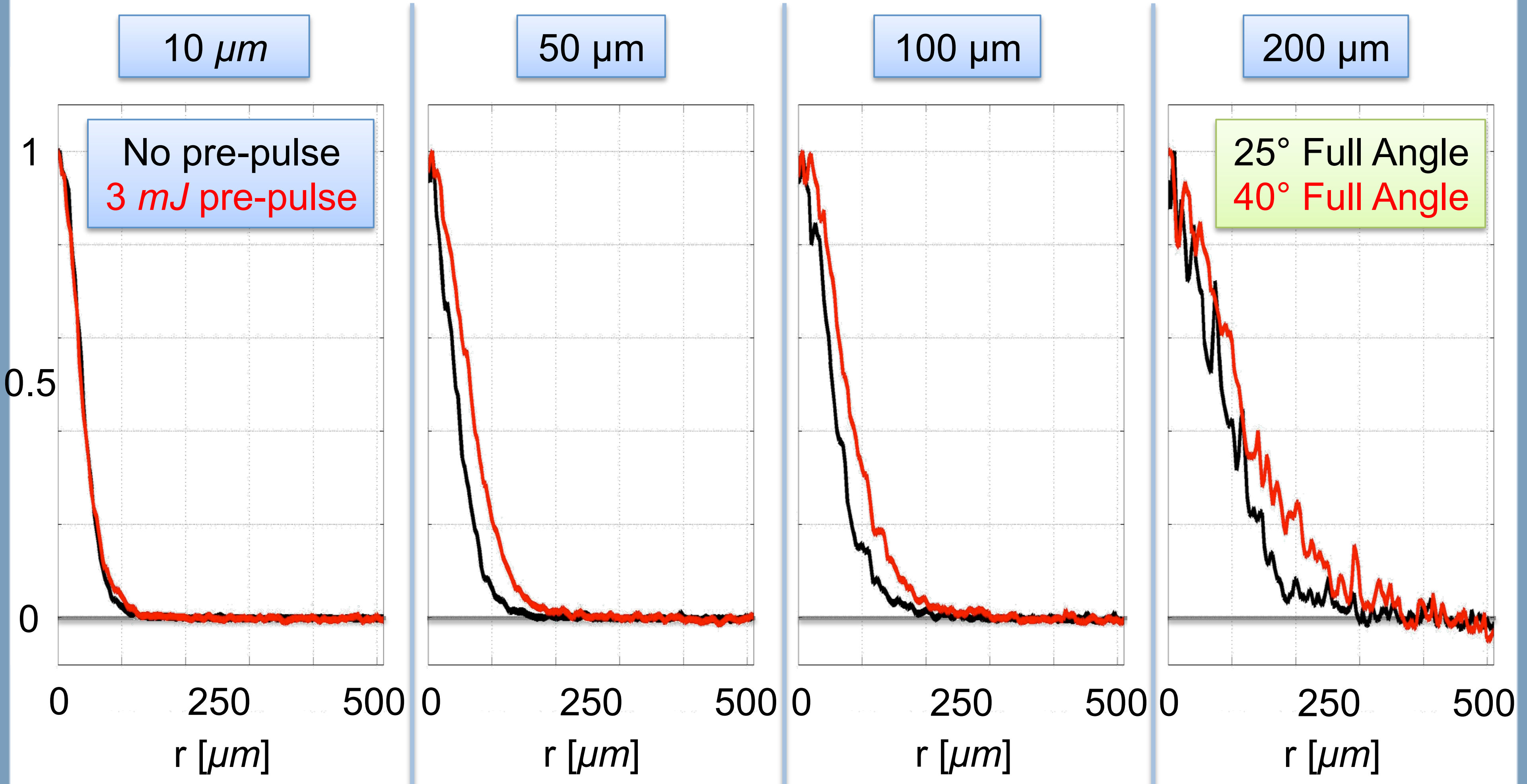
Early red shift previously observed with λ_o = 1 *μm* interaction attributed to Doppler shift from electron density profile steepening*

* Ping et al, submitted to PRL

Electron beam divergence from K_α images

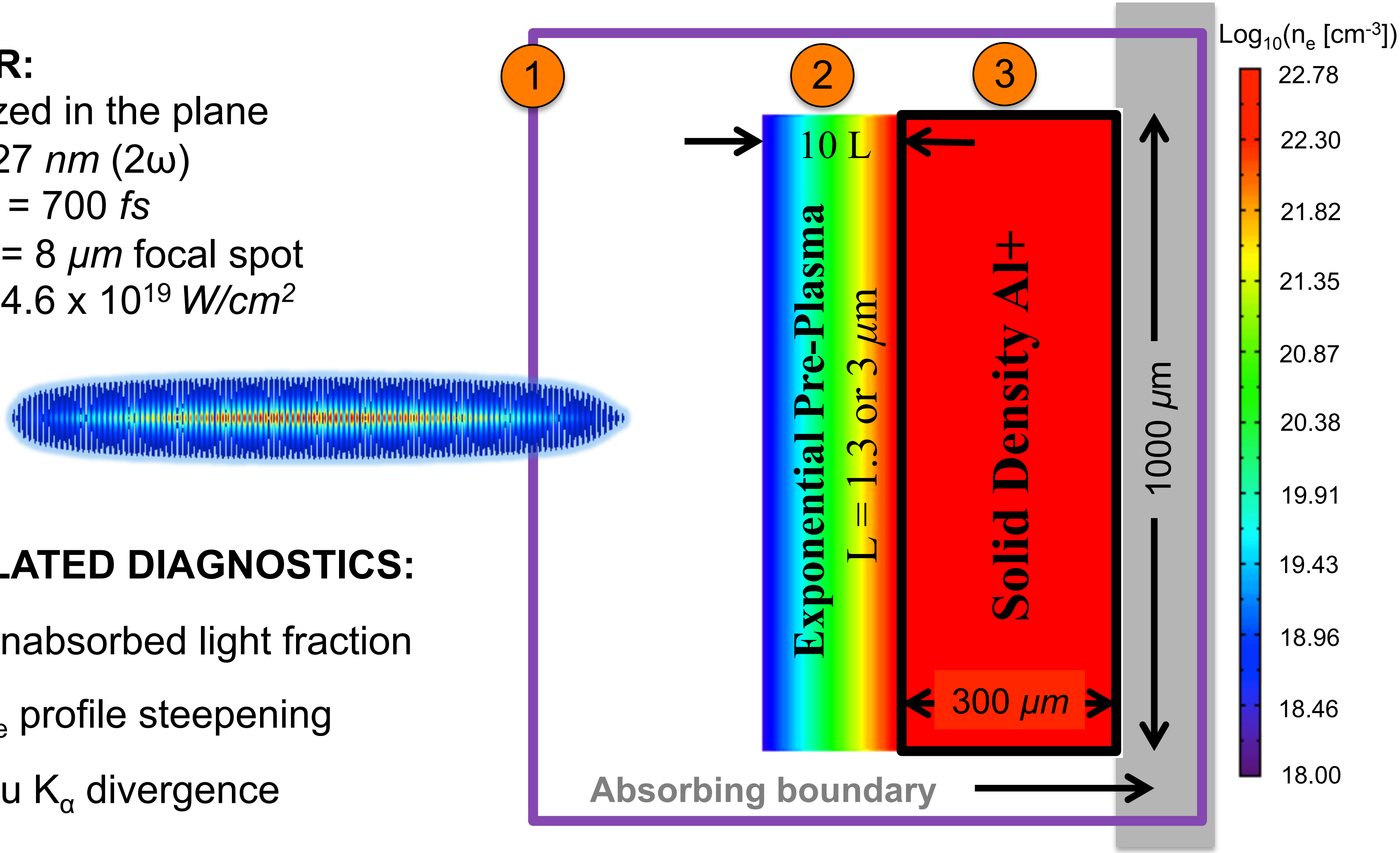


Increased K_{α} divergence (~60%) with injected pre-pulse



Full scale LPI 2D3V fully collisional kinetic PIC simulations in LSP* to gain further insight about pre-plasma effects

LASER:
Polarized in the plane
λ_o = 527 *nm* (2ω)
τ_{FWHM} = 700 *fs*
x_{FWHM} = 8 *μm* focal spot
I_{peak} = 4.6 x 10^{19} *W/cm²*



SIMULATED DIAGNOSTICS:

1. Unabsorbed light fraction
2. n_e profile steepening
3. Cu K_α divergence

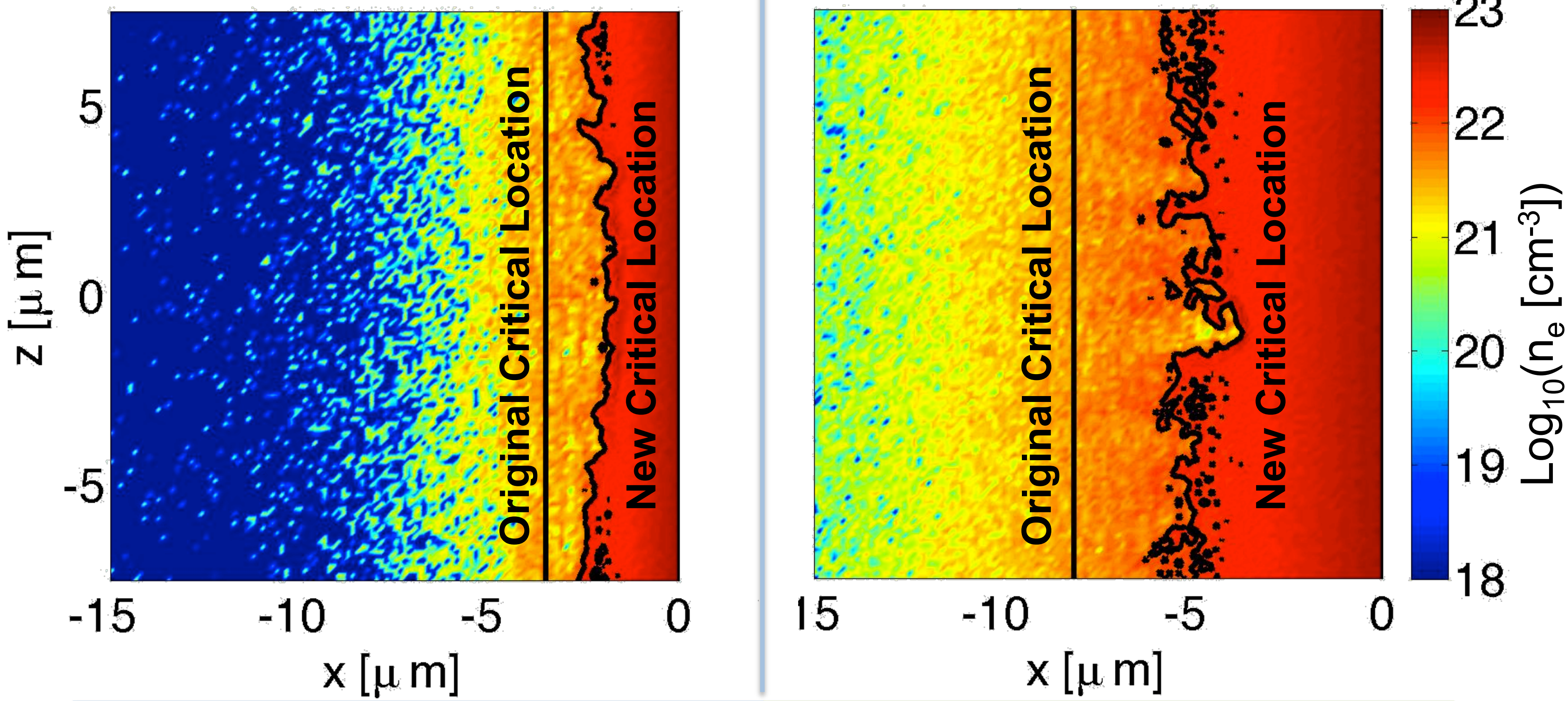
Pre-plasma environments chosen using the reflectivity data

* Welch et al, Phys. Plasmas **13**, 063105 (2006)

Simulated motion of critical surface consistent with rising edge red shift seen in specular pulse

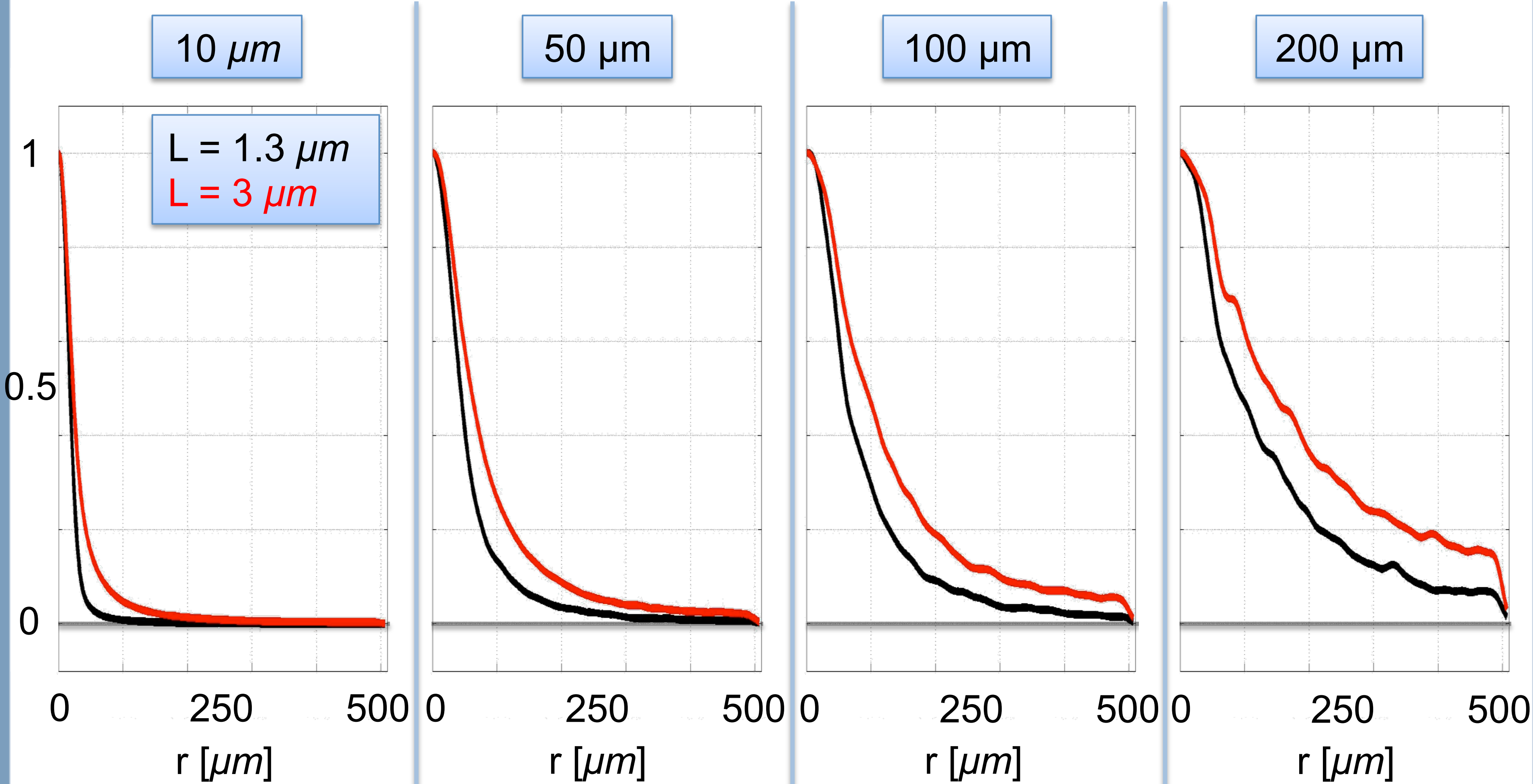
L = 1.3 *μm*

L = 3 *μm*



Experimental Results	**Simulation Results**
No pre-pulse: $\Delta\lambda/\lambda_o < 0.5\%$	L = 1.3 *μm*: $\Delta\lambda/\lambda_o \cong +1.4\%$
3 *mJ* pre-pulse: $\Delta\lambda/\lambda_o \cong +2.5\%$	L = 3 *μm*: $\Delta\lambda/\lambda_o \cong +5\%$

Increased simulated K_α divergence (~40%) with increased pre-plasma



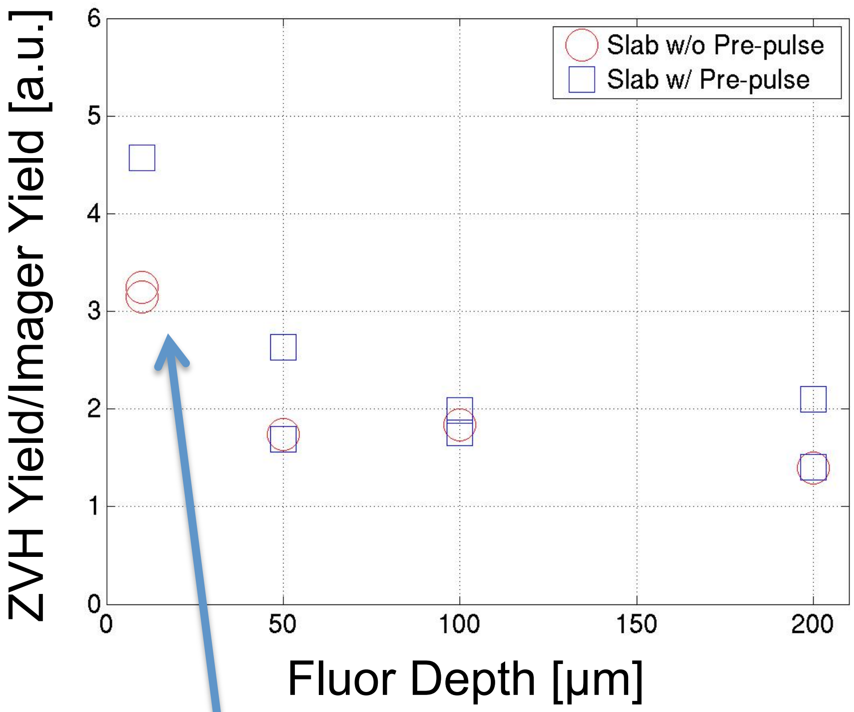
Experimental Results	**Simulation Results**
No pre-pulse: 25°	L = 1.3 *μm* : 35°
3 *mJ* pre-pulse: 40°	L = 3 *μm*: 50°

Very good agreement between experimental and simulation *trends* with increasing pre-plasma

- Full scale target simulation with self-consistent LPI and electron transport
- With increasing pre-plasma, in both experiment and our modeling we observe…
  - Decreased reflectivity
  - Increased critical density movement
  - Hotter source electron energy spectrum
  - Increased Cu K_α divergence
- Pre-plasma only unknown in simulation

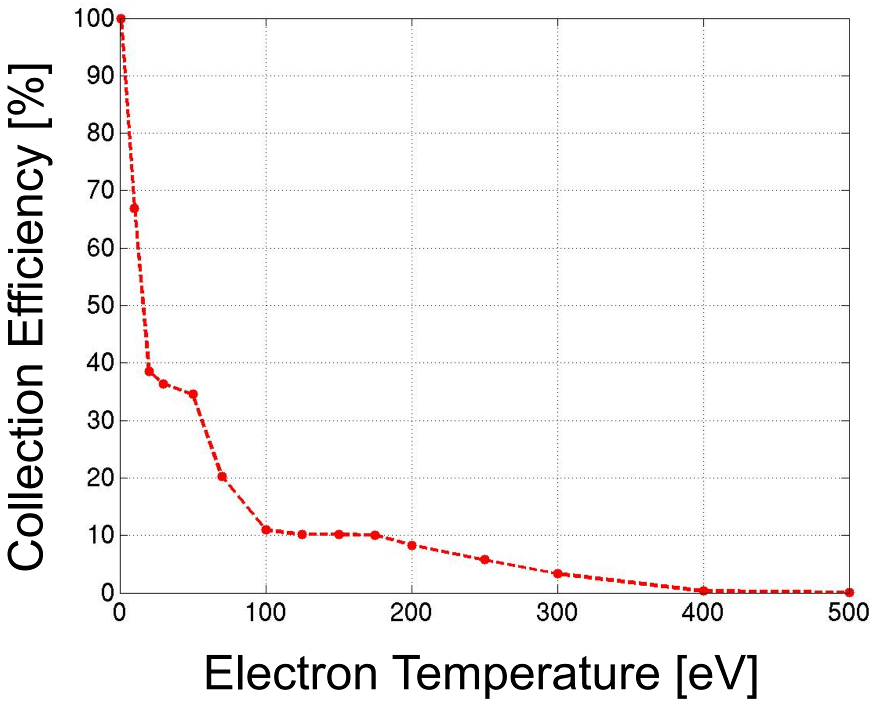
For further insight in to pre-plasma effects on experimental observables, we complete the restraint on the pre-plasma environment by simultaneous diagnostic matching

Kα imager data can be misleading

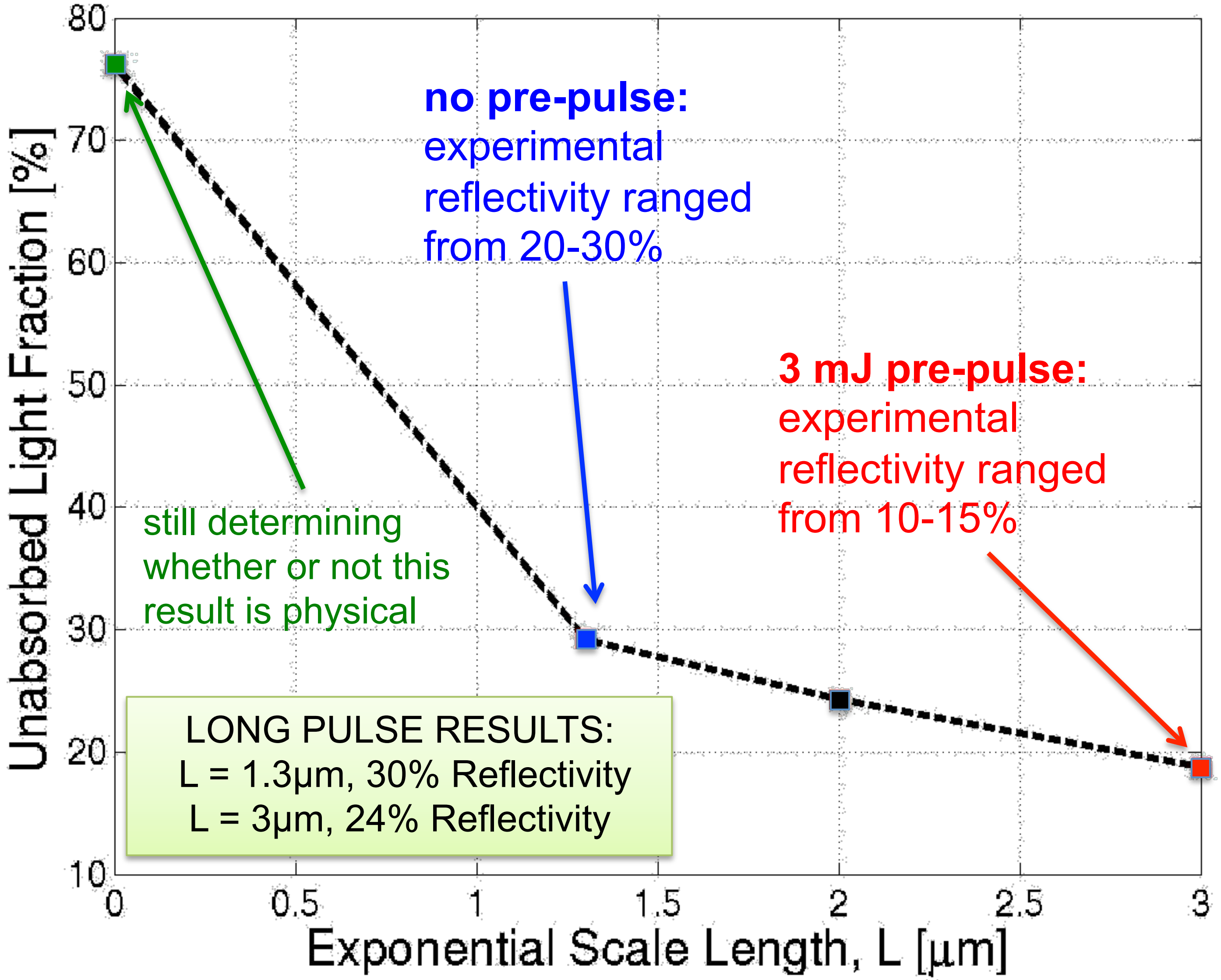


Approx. half the collection efficiency of deeper fluors

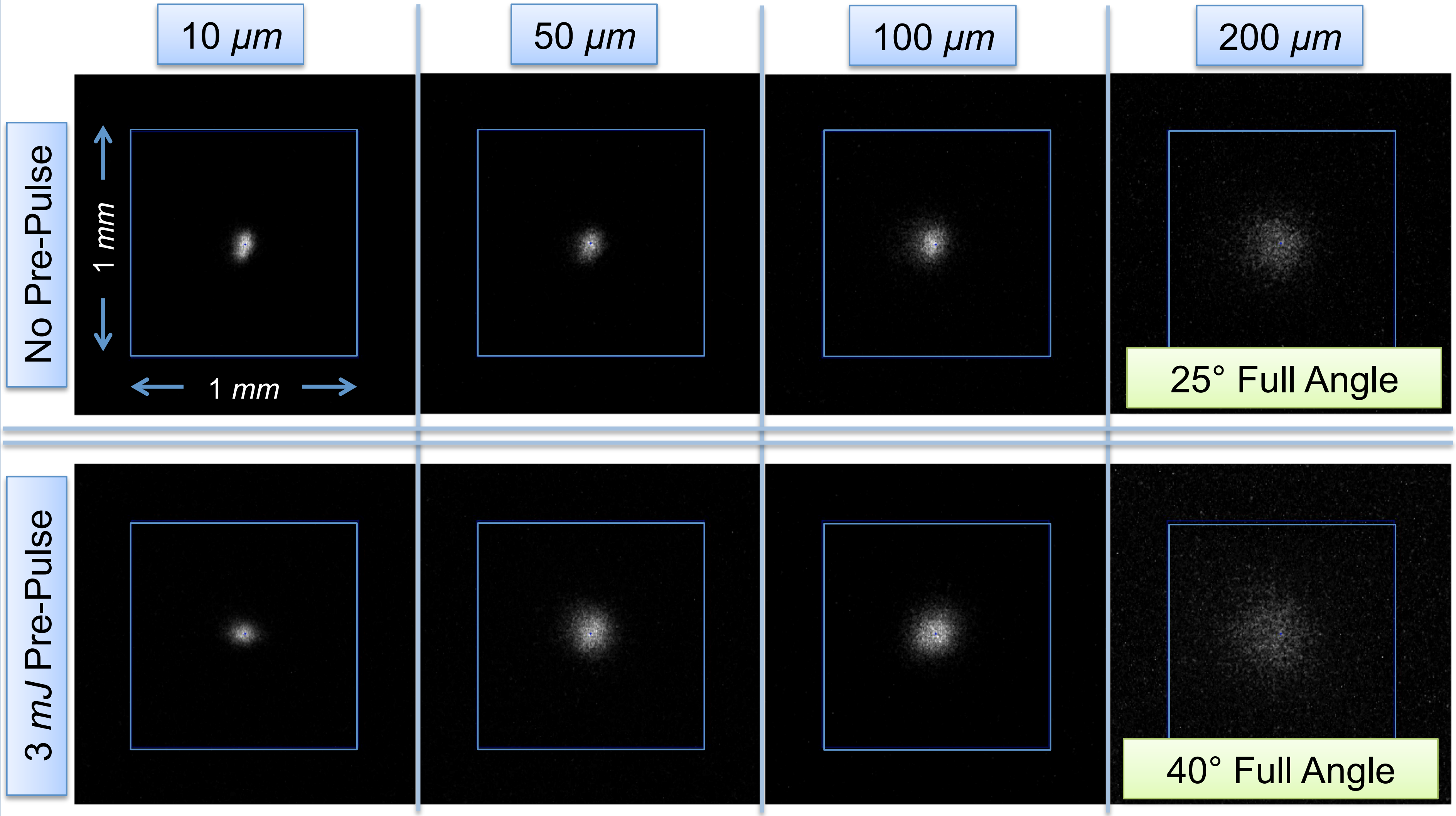
K.U. Akli [Phys. Plasmas **14**, 023102 (2007)]



Short pulse (100 *fs*) simulations used to determine pre-plasma environment by matching specular data



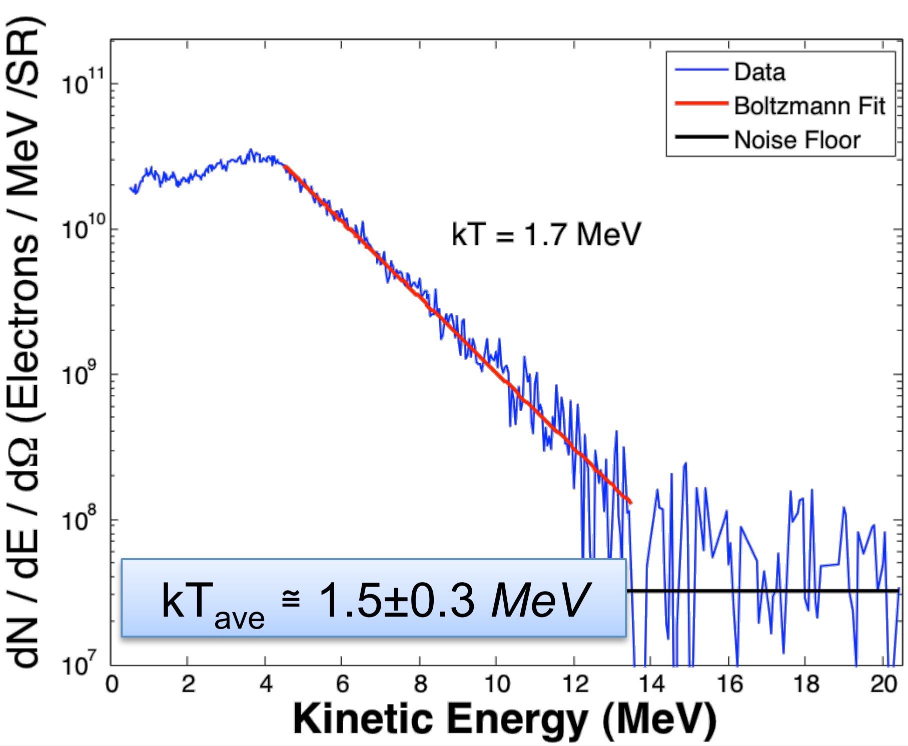
Increased Cu K_α FWHM divergence (~50%) with injected pre-pulse



Data normalized to peak value

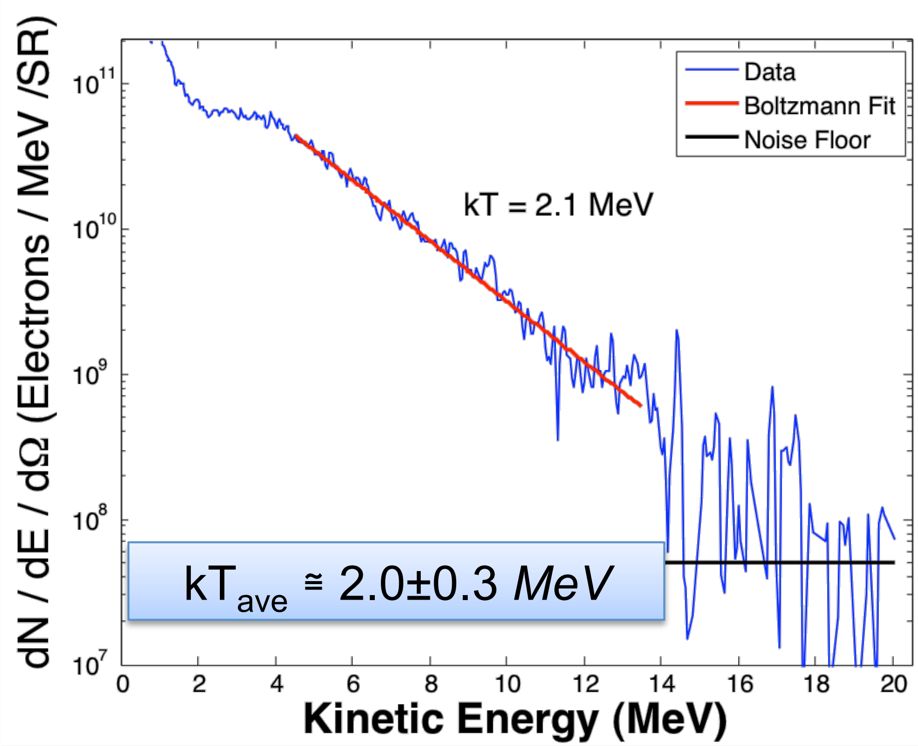
Escaped electron energy spectrum is ~30% hotter with injected pre-pulse

No Pre-pulse



$kT_{ave} \cong 1.5 \pm 0.3$ *MeV*

3 *mJ* Pre-pulse

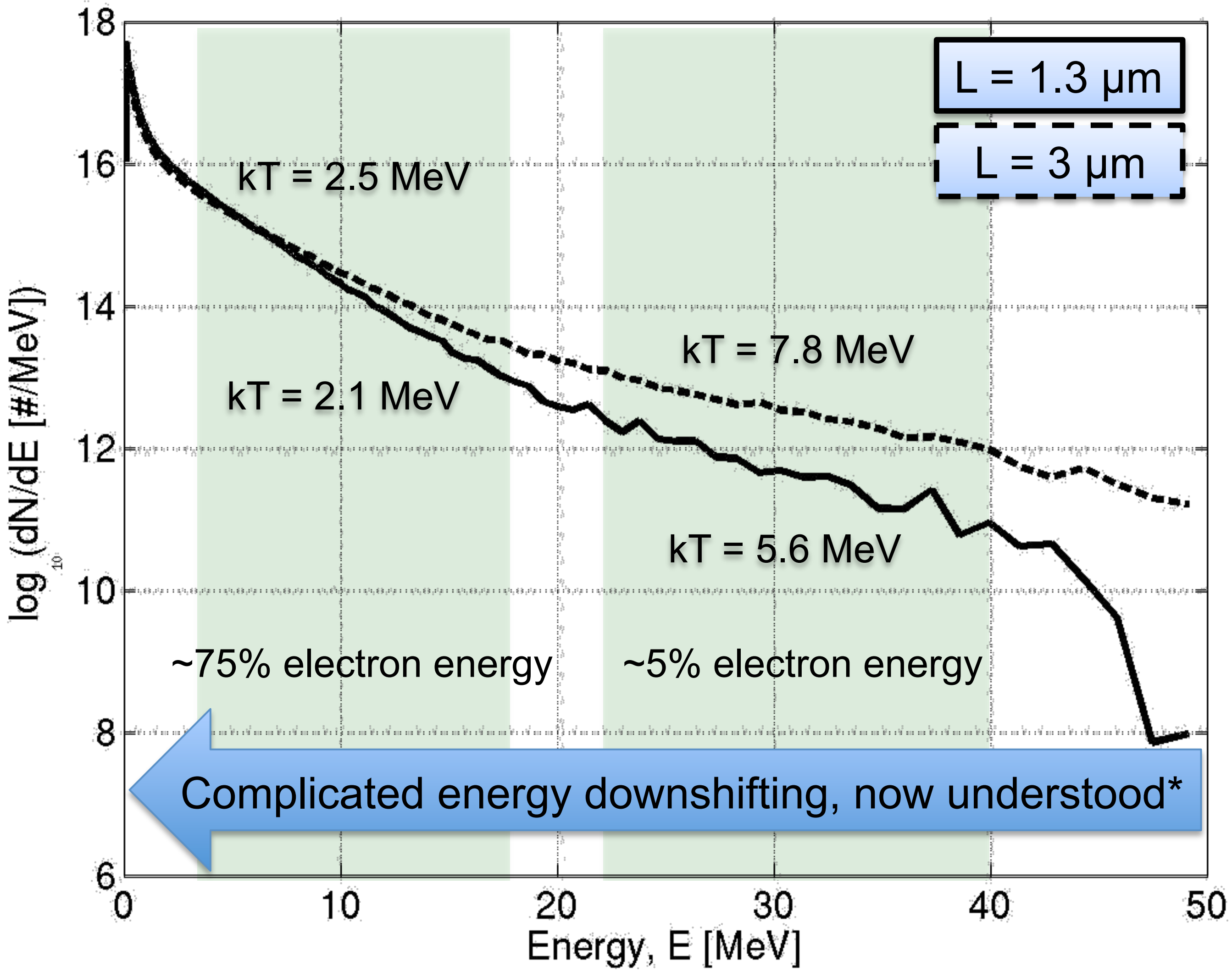


$kT_{ave} \cong 2.0 \pm 0.3$ *MeV*

As measured in vacuum, related to LPI born electrons*

* Link et al, Phys. Plasmas **18**, 053107 (2011)

Time integrated simulated SOURCE electron energy spectrum ~20-40% hotter with increased pre-plasma



Same experimental trend observed, however consistently hotter than what was measured

* Link et al, Phys. Plasmas **18**, 053107 (2011)